US009480115B2

(12) **United States Patent**
Bradford

(10) **Patent No.: US 9,480,115 B2**
(45) **Date of Patent: Oct. 25, 2016**

(54) **DYNAMIC LIGHT EMITTING DEVICE (LED) LIGHTING CONTROL SYSTEMS AND RELATED METHODS**

(71) Applicant: **Cree, Inc.**, Durham, NC (US)

(72) Inventor: **Everett Bradford**, Apex, NC (US)

(73) Assignee: **Cree, Inc.**, Durham, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 704 days.

(21) Appl. No.: **13/777,351**

(22) Filed: **Feb. 26, 2013**

(65) **Prior Publication Data**

US 2014/0239848 A1 Aug. 28, 2014

(51) **Int. Cl.**
H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0845*** (2013.01)

(58) **Field of Classification Search**
CPC H05B 33/0845
USPC 315/148–152, 307
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0106218 A1*	5/2008	Zulch	H05B 33/0845 315/291
2011/0121744 A1*	5/2011	Salvestrini et al.	H05B 33/0815 315/246
2011/0140612 A1*	6/2011	Mohan et al.	H05B 37/0218 315/149
2012/0268019 A1*	10/2012	Briggs	H05B 33/0854 315/158

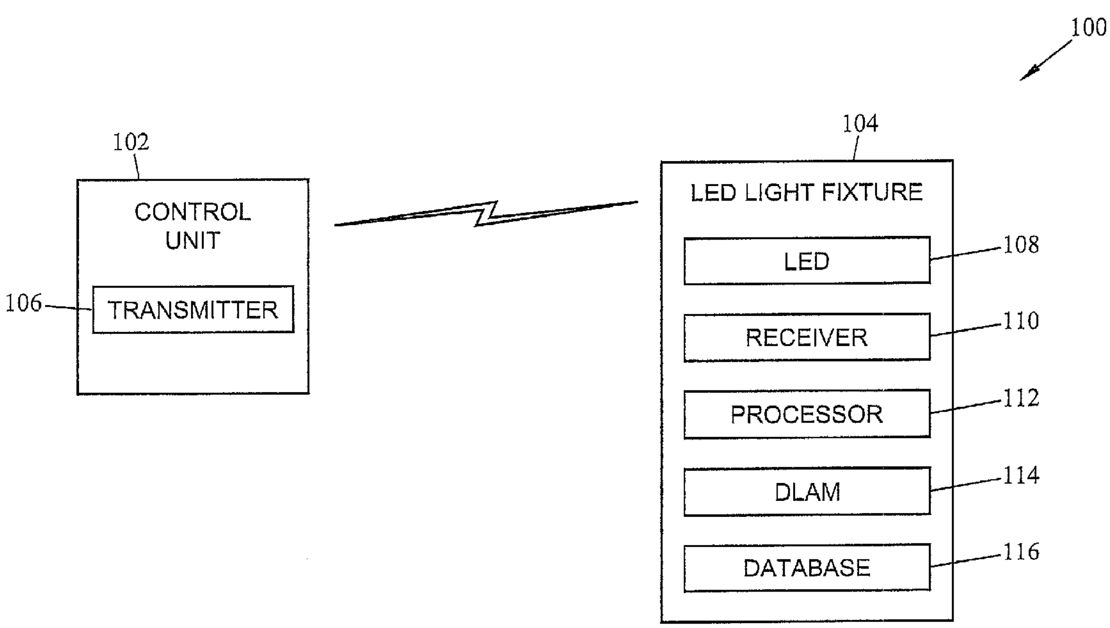
* cited by examiner

Primary Examiner — Douglas W Owens
Assistant Examiner — Jonathan Cooper
(74) *Attorney, Agent, or Firm* — Jenkins, Wilson, Taylor & Hunt, P.A.

(57) **ABSTRACT**

Dynamic light emitting device (LED) lighting adjustment systems and related methods are disclosed. In one aspect, a method can receive, at an LED lighting fixture, a lighting adjustment signal corresponding to a target lighting level and determine a delta value that represents a difference between a current lighting level of the LED lighting fixture and the target lighting level and a step time value associated with the determined delta value. The method can further include adjusting the current lighting level of the LED lighting fixture to a new current lighting level for the duration of the step time value and repeating the determining and adjusting steps until the new current lighting level equals the target lighting level.

34 Claims, 8 Drawing Sheets



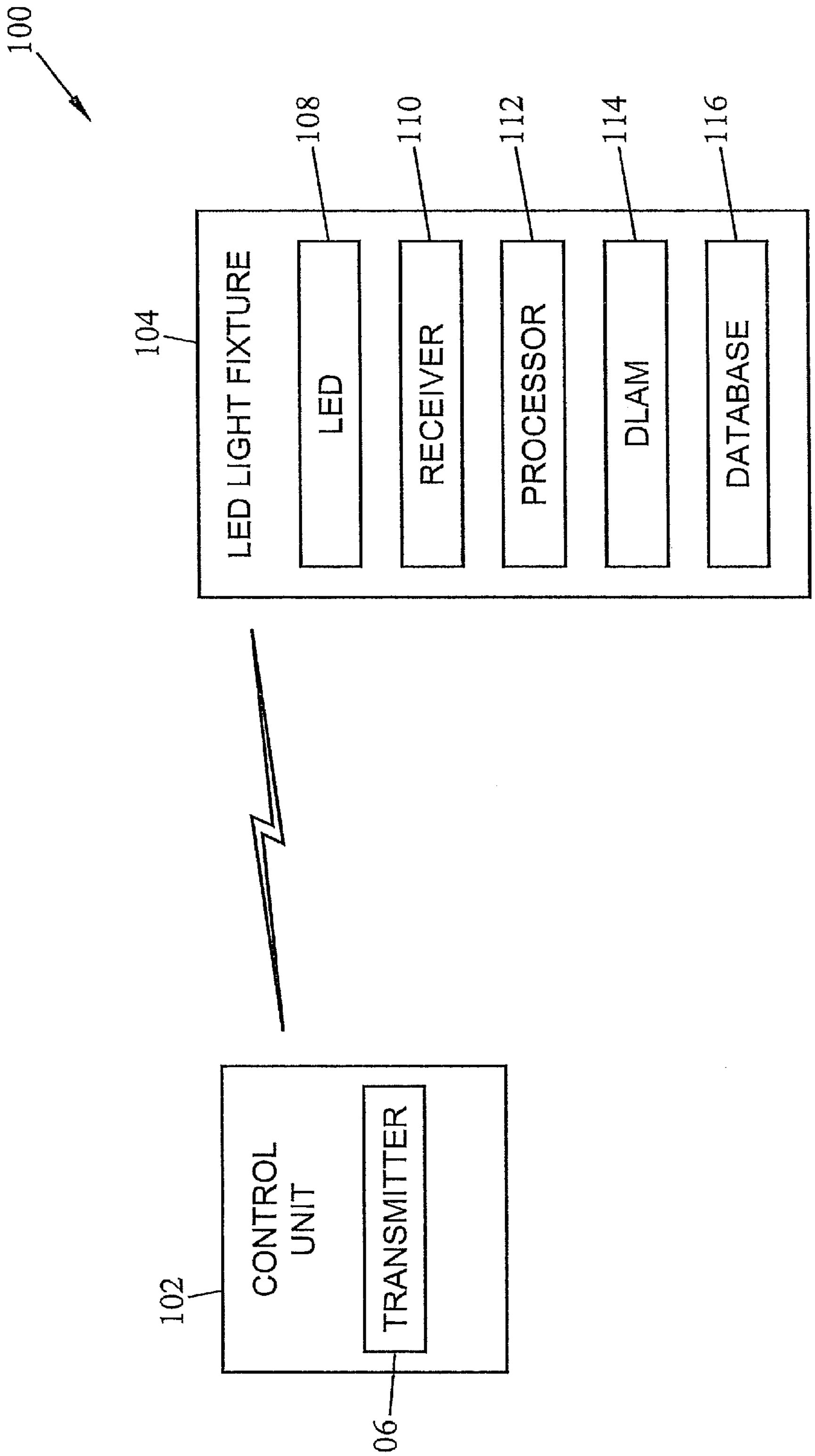

100
104
LED LIGHT FIXTURE
108
LED
110
RECEIVER
112
PROCESSOR
114
DLAM
116
DATABASE
102
CONTROL UNIT
TRANSMITTER
106

FIG. 1

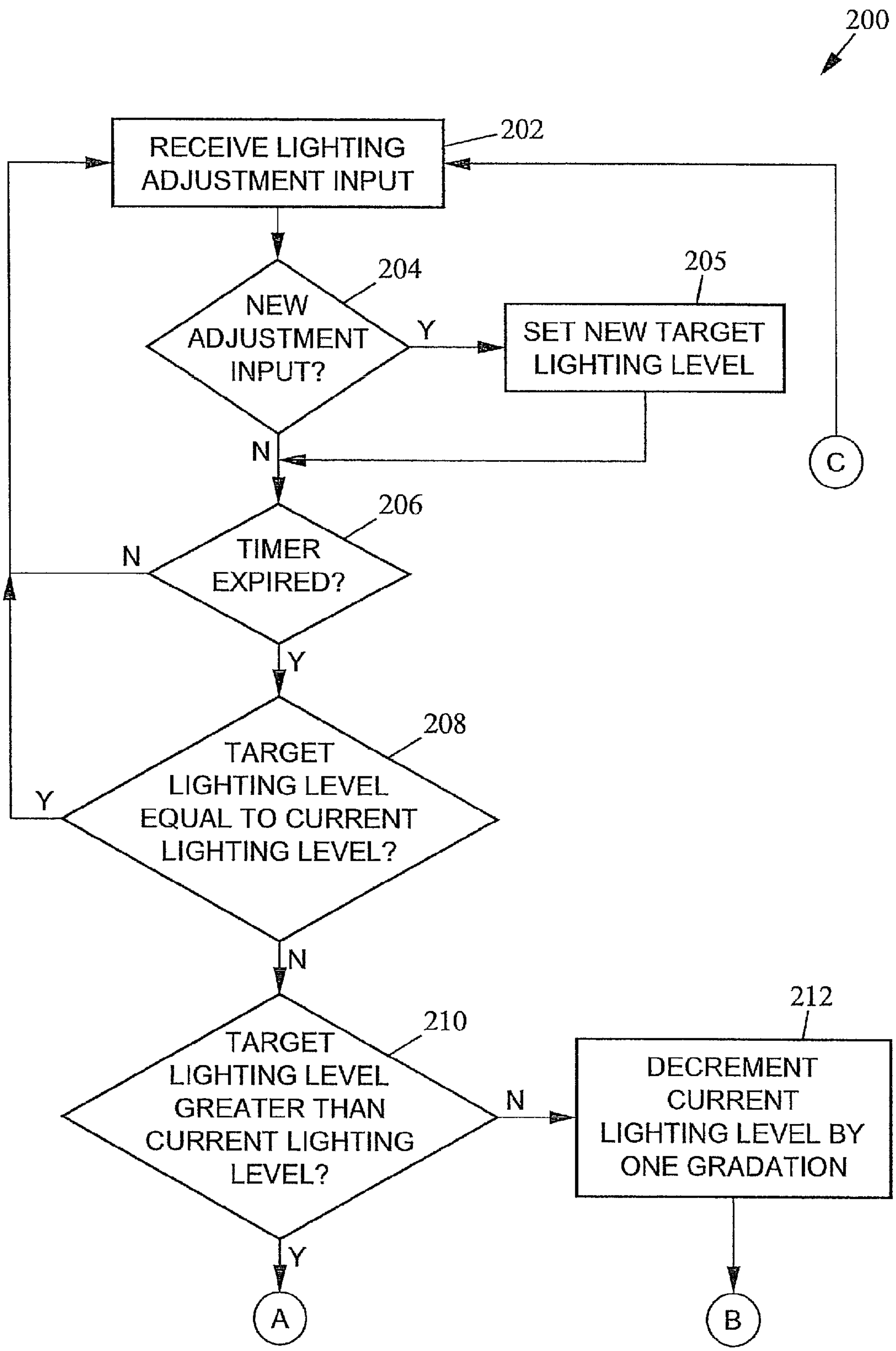

200
RECEIVE LIGHTING ADJUSTMENT INPUT
202
NEW ADJUSTMENT INPUT?
204
Y
SET NEW TARGET LIGHTING LEVEL
205
N
C
TIMER EXPIRED?
206
N
Y
TARGET LIGHTING LEVEL EQUAL TO CURRENT LIGHTING LEVEL?
208
Y
N
TARGET LIGHTING LEVEL GREATER THAN CURRENT LIGHTING LEVEL?
210
N
DECREMENT CURRENT LIGHTING LEVEL BY ONE GRADATION
212
Y
A
B

FIG. 2A

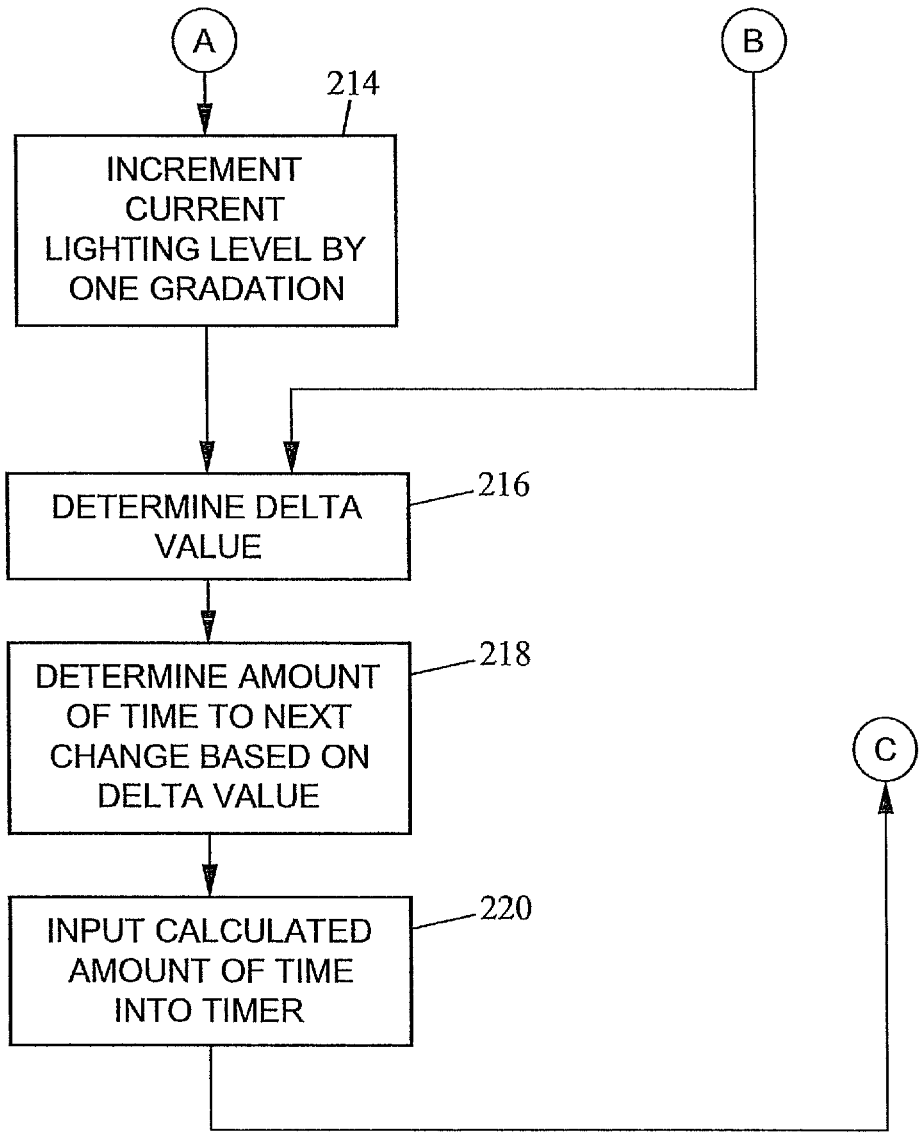

A
B
214
INCREMENT CURRENT LIGHTING LEVEL BY ONE GRADATION
DETERMINE DELTA VALUE
216
DETERMINE AMOUNT OF TIME TO NEXT CHANGE BASED ON DELTA VALUE
218
C
INPUT CALCULATED AMOUNT OF TIME INTO TIMER
220

FIG. 2B

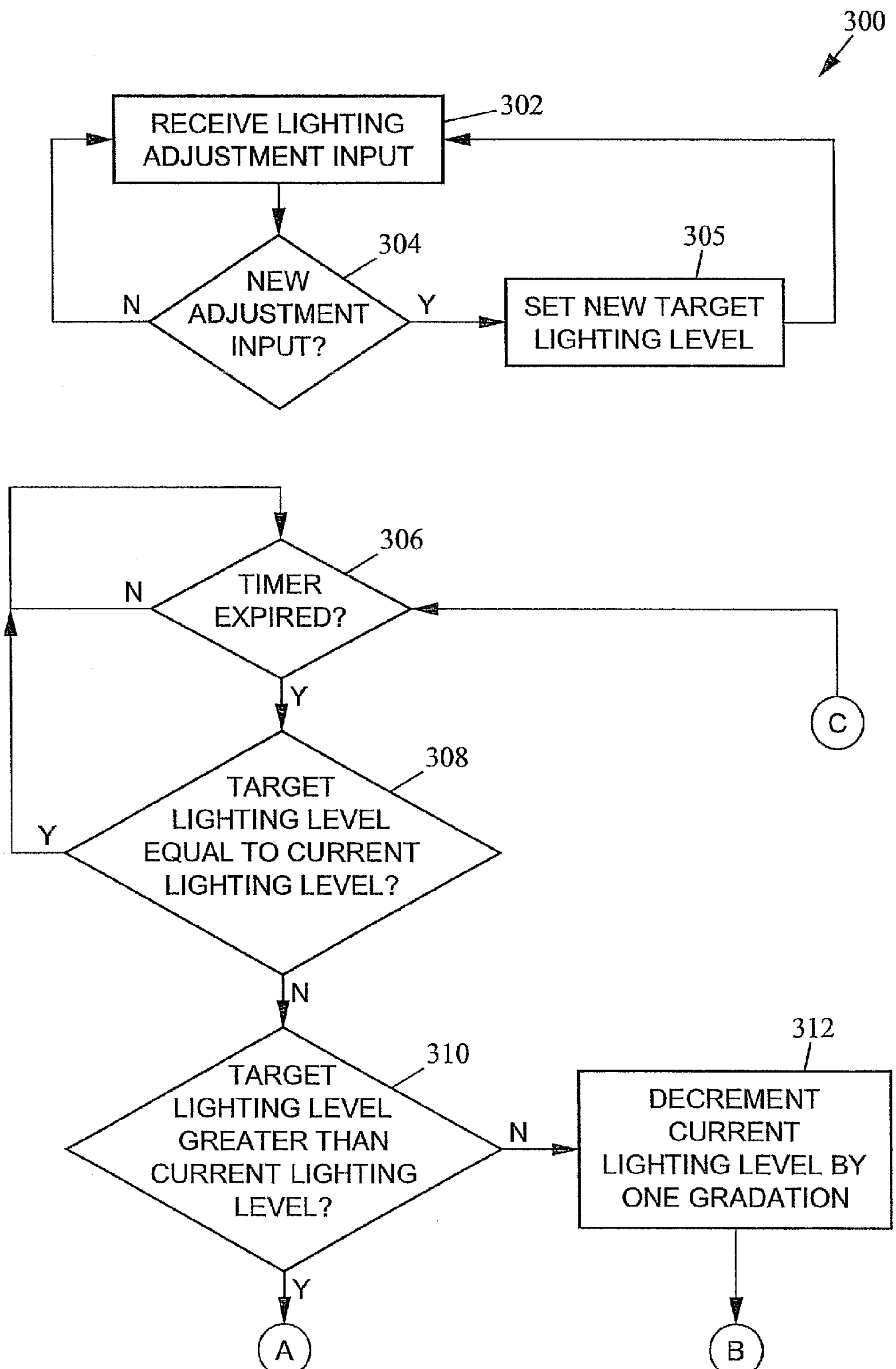

300
RECEIVE LIGHTING ADJUSTMENT INPUT
302
NEW ADJUSTMENT INPUT?
304
N
Y
SET NEW TARGET LIGHTING LEVEL
305
TIMER EXPIRED?
306
N
Y
C
TARGET LIGHTING LEVEL EQUAL TO CURRENT LIGHTING LEVEL?
308
Y
N
TARGET LIGHTING LEVEL GREATER THAN CURRENT LIGHTING LEVEL?
310
N
Y
DECREMENT CURRENT LIGHTING LEVEL BY ONE GRADATION
312
A
B

FIG. 3A

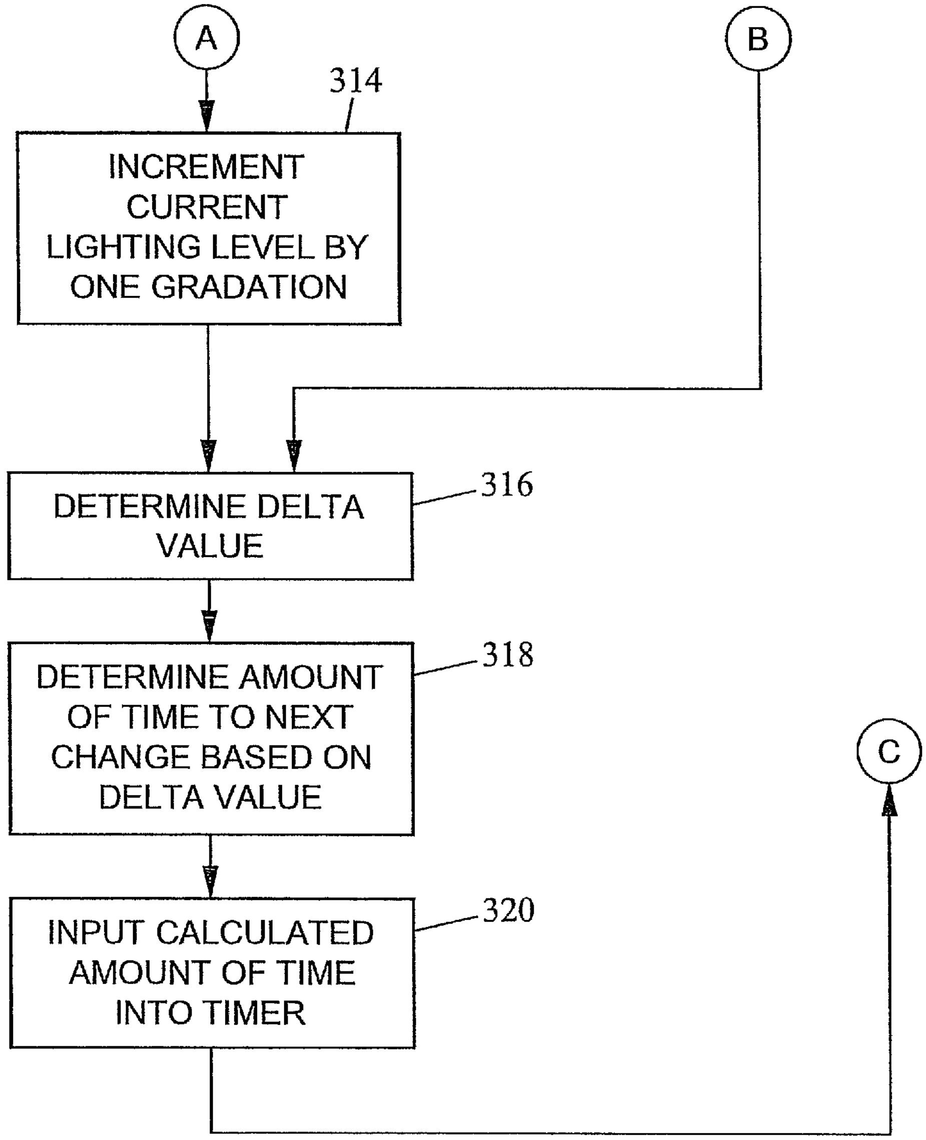

A
B
314
INCREMENT CURRENT LIGHTING LEVEL BY ONE GRADATION
316
DETERMINE DELTA VALUE
318
DETERMINE AMOUNT OF TIME TO NEXT CHANGE BASED ON DELTA VALUE
C
320
INPUT CALCULATED AMOUNT OF TIME INTO TIMER

FIG. 3B

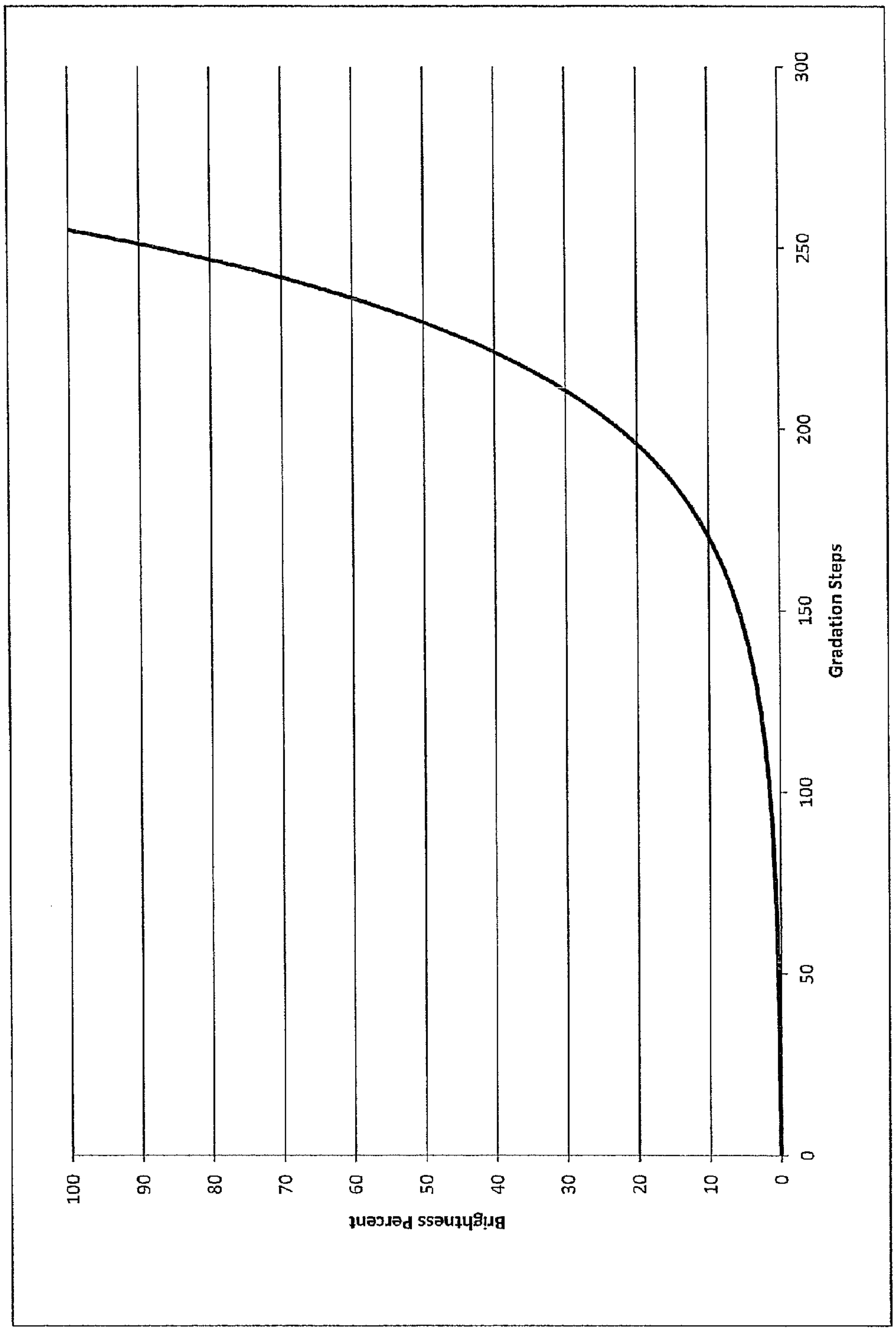

Brightness Percent
0
10
20
30
40
50
60
70
80
90
100
Gradation Steps
0
50
100
150
200
250
300

FIG. 4

500

502

Gradation Step	Brightness %
0	0.097317059
1	0.1
2	0.102756907
3	0.105589819
4	0.108500833
5	0.1114921
6	0.114565833
7	0.117724307
8	0.120969856
9	0.124304883
10	0.127731853
11	0.131253301
12	0.134871833
13	0.138590124
14	0.142410925
15	0.146337062
16	0.150371438
17	0.154517039
18	0.15877693
19	0.163154263
20	0.167652274
21	0.172274291
22	0.177023734
23	0.181904113
24	0.186919041
25	0.192072225

504

Gradation Step	Brightness %
151	5.910899064
152	6.073857057
153	6.241307649
154	6.413374699
155	6.590185478
156	6.771870765
157	6.958564947
158	7.150406114
159	7.347536163
160	7.550100905
161	7.758250169
162	7.972137914
163	8.191922345
164	8.417766029
165	8.649836013
166	8.888303951
167	9.133346228
168	9.385144093
169	9.643883792
170	9.909756703
171	10.18295948
172	10.46369421
173	10.75216853
174	11.04859582
175	11.35319534
176	11.66619238

506

Gradation Step	Brightness %
230	50.66690889
231	52.06374847
232	53.49909761
233	54.974018
234	56.48960057
235	58.04696635
236	59.64726725
237	61.29168696
238	62.98144179
239	64.71778159
240	66.50199067
241	68.33538873
242	70.21933188
243	72.15521358
244	74.14446574
245	76.18855974
246	78.2890075
247	80.44736266
248	82.66522167
249	84.94422498
250	87.2860583
251	89.69245379
252	92.16519136
253	94.70610001
254	97.31705915
255	100

FIG. 5

600

Delta Value	Step Time (ms)
0	16.384
1	16.384
2	16.32
3	16.256
4	16.128
5	15.936
6	15.808
7	15.552
8	15.296
9	15.04
10	14.72
11	14.4
12	14.016
13	13.568
14	13.12
15	12.608
16	12.096
17	11.584
18	11.008
19	10.368
20	9.728
21	9.024
22	8.32
23	7.552
24	6.784
25	5.952
26	5.12
27	4.224
28	3.328
29	2.368
30	1.408
31+	0.384

FIG. 6

DYNAMIC LIGHT EMITTING DEVICE (LED) LIGHTING CONTROL SYSTEMS AND RELATED METHODS

TECHNICAL FIELD

The subject matter disclosed herein relates generally to light emitter systems and related methods. More particularly, the subject matter disclosed herein relates to dynamic light emitting device (LED) lighting control systems and related methods.

BACKGROUND

Light emitters, such as light emitting diodes or devices (LEDs), are solid state devices that convert electrical energy into light. LEDs are widely used in lighting systems that provide cost effective illumination in commercial and residential locations. Currently, digital dimming systems for adjusting the brightness of LED are being utilized to control and manage the aforementioned LED-based lighting systems. However, due to the digital nature and the discrete levels/steps of brightness that are characteristic of these LED control systems, certain illumination problems can arise during normal operation. For example, it is not uncommon for the illumination emitted by an LED light fixture to visually "jump" to each discrete level as a control switch (e.g., a dimmer slider) is adjusted. Typically, viewing such an uneven transition between distinct levels of illumination is quite noticeable and, in some instances, unpleasant to the human eye.

Accordingly, there exists a need for dynamic LED lighting control systems and related methods.

SUMMARY

In accordance with this disclosure, novel dynamic light emitting device (LED) lighting control systems and related methods are disclosed herein. It is, therefore, an object of the disclosure herein to provide exemplary systems and methods that can comprise receiving, at a LED lighting fixture, a lighting adjustment signal corresponding to a target lighting level and determining a delta value that represents a difference between a current lighting level of the LED lighting fixture and the target lighting level and a step time value associated with the determined delta value. The method further comprises adjusting the current lighting level of the LED lighting fixture to a new current lighting level for the duration of the step time value and repeating the determining and adjusting steps until the new current lighting level equals the target lighting level.

The subject matter described herein can be implemented in hardware, software, firmware, or any combination thereof. For example, the subject matter described herein can be implemented in software (e.g., a "function" or "module") executed by a hardware-based processor. In one exemplary implementation, the subject matter described herein can be implemented using a non-transitory computer readable medium having stored thereon executable instructions that when executed by the processor of a computer control the processor to perform steps. Exemplary non-transitory computer readable media suitable for implementing the subject matter described herein can for example comprise chip memory devices or disk memory devices accessible by a processor, programmable logic devices, and application specific integrated circuits. In addition, a computer readable medium that implements the subject matter described herein can be located on a single computing platform or can be distributed across plural computing platforms.

These and other objects of the present disclosure as can become apparent from the disclosure herein are achieved, at least in whole or in part, by the subject matter disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present subject matter will be more readily understood from the following detailed description which should be read in conjunction with the accompanying drawings that are given merely by way of explanatory and non-limiting example, and in which:

FIG. **1** is a block diagram illustrating a dynamic LED lighting control system according to one aspect of the disclosure herein;

FIGS. **2**A and **2**B depict a flow chart illustrating a dynamic LED lighting control method according to one aspect of the disclosure herein;

FIGS. **3**A and **3**B depict a flow chart illustrating a second dynamic LED lighting control method according to one aspect of the disclosure herein;

FIG. **4** is a graph illustrating an exemplary association between brightness percentage and gradation steps corresponding to an LED light fixture according to one aspect of the disclosure herein;

FIG. **5** depicts an exemplary table illustrating the numerical association between brightness percentage and gradation steps corresponding to an LED light fixture according to one aspect of the disclosure herein; and

FIG. **6** is an exemplary table illustrating the association between different delta values and step time values according to one aspect of the disclosure herein.

DETAILED DESCRIPTION

The subject matter disclosed herein is directed to dynamic light emitting device (LED) lighting control systems and related methods. In one aspect, the present subject matter can comprise a software process to enable the dimming of an LED light source to appear visually smooth by eliminating the visible transitions between brightness levels. For example, a change from a dimming input device, such as a user moving a slider or knob on a manual dimmer, establishes a target brightness level for the LED light source. The software process that controls the brightness can then adjust the illumination level of the LED light source in a manner that traverses through all of the brightness levels exiting between the current brightness light level (e.g., the initial illumination level prior to the user's control input) and the target light level (e.g., the illumination level corresponding to the received control input). Notably, the software process continuously changes the speed or rate at which the process proceeds to each distinct brightness level. In some aspects, the speed can be established by applying a mathematical operation on a delta value, which represents the difference between the current lighting level and the target lighting level. Consequently, the LED light output can quickly track user inputs when the current delta value is large, but can gradually approach the target lighting level as the delta value becomes smaller. This manner of controlling an LED light fixture not only prevents visible steps between brightness levels produced by a digitally-dimmed control system but also improves the aesthetics of the LED light source as a new brightness level is established.

Reference will be made in detail to possible aspects or embodiments of the subject matter herein, one or more examples of which are shown in the figures. Each example is provided to explain the subject matter and not as a limitation. In fact, features illustrated or described as part of one embodiment can be used in another embodiment to yield still a further embodiment. It is intended that the subject matter disclosed and envisioned herein covers such modifications and variations.

FIG. **1** is a block diagram illustrating dynamic light emitting device (LED) lighting adjustment system according to one aspect of the disclosure herein. Referring to FIG. **1**, an exemplary dynamic LED lighting adjustment system generally designated **100** can comprise at least one control unit **102** and at least one LED fixture **104**. Although system **100** only depicts a single control unit **102** and a single LED light fixture **104**, additional control units and LED light fixtures can be utilized without departing from the scope of the present subject matter. In some aspects, control unit **102** and LED light fixture **104** can be communicatively connected together either via a wireless connection (as shown in FIG. **1**) or a wired connection (not shown). Control unit **102** can comprise any type of controlling mechanism utilized by a dimmer switch, knob, slider, or the like. If communicatively connected to LED light fixture **104** via a wireless means, then control unit **102** can be provisioned with a transmitter unit **106**. In some aspects, transmitter unit **106** can comprise a radio frequency (RF) transmitter, an infrared transmitter, a WiFi transmitter, or any other like wireless transmitter unit.

Likewise, LED light fixture **104** can be equipped with a receiver unit **110** (e.g., a radio receiver or a wired receiver unit) that can be configured to receive any wireless signal transmitted from transmitter unit **106**. Regardless of the manner in which control unit **102** and LED light fixture **104** are communicatively connected, LED light fixture **104** can further comprise an LED **108**, a processing unit **112**, a dynamic LED adjustment module (DLAM) **114**, and database **116**. Specifically, LED light fixture **104** can comprise an LED **108**, such as an LED diode or chip, which can be at least partially covered such as by a lens or encapsulant. LED light fixture **104** can also comprise a processor such as processing unit **112** (e.g., a microcontroller or microprocessor) and software, such as software-based or firmware-based DLAM **114**. In one aspect, processing unit **112** can comprise a microcontroller configured to send a pulse width modulation (PWM) signal to adjust (e.g., increase or decrease) the brightness of LED **108**. Processing unit **112** can also comprise a clock timer (e.g., a timer routine and/or function) configured to receive a time value input that determines when the PWM signal is sent. In some aspects, processing unit **112** can utilize DLAM **114** to process a lighting adjustment signal sent by control unit **102**. For example, DLAM **114** can be used to compare the current lighting level emitted by LED light fixture **104** with a target lighting level associated with the received lighting adjustment signal. Based on i) a delta value that represents the difference of the current lighting level and the target lighting level and ii) the current brightness level setting (e.g., gradation step) itself, DLAM **114** can modify the received lighting adjustment signal in a manner that produces a smooth illumination transition (e.g., increasing or dimming the LED) as LED lighting fixture adjusts the lighting level from the current lighting level to the target lighting level (e.g., the desired lighting level). Notably, DLAM **114** can be configured to transition or sweep through all the lighting levels between the current lighting level and the target lighting level at a variable rate. In some aspects, DLAM **114** can produce a variable rate that comprises a faster change rate (i.e., the amount of time in which the LED light fixture emits a brightness gradation level/step before being adjusted to the next gradation step) if the current lighting level gradation step is far (i.e., a large numerical difference in gradation steps) from the target lighting level gradation step. DLAM **114** can also be configured to decrease the change rate as the current lighting level gradation step approaches the target lighting level step. An exemplary manner in which DLAM **114** dynamically adjusts the brightness level of LED lighting fixture **104** upon receiving a lighting adjustment signal/command is described in FIG. **2** below.

FIG. **2** illustrates a flow chart of a method **200** for dynamically adjusting the illumination output of an LED lighting fixture. In some aspects, the steps of method **200** can be implemented upon the execution of DLAM **114** by processing unit **112**. Referring to FIG. **2**, method **200** can comprise step **202** where a lighting adjustment input is received. In one aspect, a user can adjust a control unit (e.g., control unit **102**), such as a dimmer slider, configured to control the illumination output of an LED light fixture. Upon adjusting the dimmer slider, a transmitter unit (e.g., transmitter unit **106**) associated with the dimmer switch can be configured to transmit a wireless signal that comprises a lighting adjustment input command to the LED light fixture (e.g., LED light fixture **104**). For example, consider a dimmer switch that can be set to any one of 256 level/step settings that corresponds to the lighting gradation level/steps of an LED light fixture (e.g., level settings ranging from 0 to 255 wherein gradation step 0 is off and gradation step 255 is the maximum illumination output of the LED light fixture). To illustrate this aspect, consider FIG. **4** which depicts an exemplary logarithmic curve that visually represents an association of the brightness percent and the lighting gradation steps of an LED light fixture. Similarly, FIG. **5** depicts three separate sections **502-506** of a table that contains the numerical data used to plot the logarithmic curve depicted in FIG. **4**. Both FIGS. **4** and **5** illustrate the notion that as the gradation steps increase linearly, the brightness percent of the LED light fixture increases exponentially. Although the example in FIG. **2** describes an embodiment that utilizes 256 gradation steps, any number of gradation steps can be utilized without departing from the scope of the present subject matter.

Returning to the discussion of step **202** in FIG. **2**, consider a scenario where the dimmer slider is initially set to a gradation step of 158. In some aspects, the initial 158th gradation step can be mapped or associated with a particular lumen level or brightness percentage of the LED light fixture being controlled. For example, referring to either the curve depicted in FIG. **4** or table **500** in FIG. **5**, the 158th gradation step is depicted as being associated with 7.15 brightness percent of the LED light fixture. Thus, when the LED light fixture is set to the 158th gradation step, the light emitted is equal to 7.15% of the maximum illumination output of the LED light fixture. Further suppose that, a user decides to utilize the dimmer slider to increase the current lighting level (e.g., initial lighting level) of the LED light fixture from the 158th gradation step to a desired "target" lighting level that corresponds to the 175th gradation step. By adjusting the dimmer slider, the user utilizes the control unit to send a lighting adjustment signal containing the target lighting level to the LED light fixture. At this point, method **200** proceeds to step **204** to initiate a number of checks in order to process the lighting adjustment signal.

In step **204**, a determination is made as to whether the received lighting adjustment signal is new. In some aspects, step **204** can be an optional step used in wireless control systems. Because a wireless system can inadvertently send a previously transmitted lighting adjustment signal to the LED light fixture, step **204** can function as a reliability check that ensures that the received input command signal is new. If the received lighting adjustment signal is determined to be a new adjustment input, then method **200** can then proceed to step **205** where the input command signal is stored as a new target lighting level. Afterwards, method **200** can continue to step **206**. If the received lighting adjustment signal is not a new adjustment input, then method **200** can continue directly to step **206** where a determination is made as to whether a clock timer (e.g., a portion of a processor in the LED light fixture) has expired. In some aspects, the query in block **206** can occur on a continuous basis, regardless of whether a new adjustment input is made (i.e., see block **204**). In some aspects, the clock timer mechanism included in the LED light fixture can receive a step time value (explained below) and waits until the step time value expires before proceeding to the steps of method **200**. Specifically, if the step time value has not expired, method **200** can loop back up to step **202**. If the step time value has expired, then method **200** can continue to step **208**.

In step **208**, a determination can be made as to whether the target lighting level is equal to the current lighting level. If the two lighting levels match, then the target lighting level has been attained and method **200** can loop back to step **202**. Returning to the previous example, once the current lighting level is incremented to the 175th gradation step (and thus is equal to the target lighting level of 175), the LED lighting fixture has achieved the desired lighting level.

If the two lighting levels do not match, method **200** can continue to step **210** where a determination can be made as to whether the target lighting level is greater than the current lighting level (i.e., the lighting adjustment signal directs the LED light fixture to increase its brightness level). If the target light level is not greater than the current lighting level, then method **200** can continue to step **212** where the current lighting level can be decremented by one step. However, if the target lighting level is greater than the current lighting level, then method **200** can proceed to step **214** where the current lighting level is incremented by one step. Returning to the previous example, if the current lighting level is equal to 158 and the target lighting level is equal to 175, then the current lighting level can be incremented by one gradation step to a new current lighting level of 159. Notably, the brightness percentage of the LED light fixture is increased from 7.15% to 7.35% (see FIG. **4** or **5**).

In step **216**, a delta value is determined. In some aspects, the delta value can be equal to the magnitude or absolute value of the numerical difference between the current lighting level and the target lighting level. Continuing with the example presented above, the delta value would equal 16, which is equal to the absolute value of the difference of 159 (i.e., the "new" current lighting level) and **175** (i.e., the target lighting level).

In step **218**, the amount of time (i.e., a step time value) before the next gradation change can be determined. In some aspects, processing unit **112** executing DLAM **114** can calculate an amount of time in which the LED light fixture emits light at the current lighting level before the current lighting level is incremented to the next gradation level/step (i.e., a "new" current lighting level). In one aspect, the delta value can be received by or used in a mathematical formula or a polynomial as an input to determine a step time value. In another aspect, the delta value can be used to query a lookup table to obtain a step time value. Returning to the previous example, the delta value of 16 can be used to query a lookup table, such as table **500** depicted in FIG. **6**. As shown in FIG. **6**, a time value of 12.096 milliseconds corresponds with a delta value of 16.

In step **220**, the calculated amount of time is input into the timer. In one aspect, the determined step time value can be used as input for the clock timer utilized in step **206**. For example, the step time value of 12.096 milliseconds can be provided as input to the clock timer in LED lighting device **104**. Once the time value of 12.096 milliseconds expires, then the comparison of the current lighting level and the target lighting level can be made. The method **200** then can loop back to step **202**.

Upon looping back to step **202**, method **200** can continue until the target lighting level is achieved. Notably, each iteration of method **200** can adjust the current lighting level closer to the target lighting level by one step or level (i.e., increments or decrements by one step). During each iteration of method **200**, the LED light fixture can be illuminated to the brightness percentage corresponding to the new current lighting level for an amount of time corresponding to the new calculated/determined step time value (which is based on the current delta value).

FIG. **3** illustrates a flow chart of a method **300** for dynamically adjusting the illumination output of an LED lighting fixture. In some aspects, the steps of method **300** can be implemented upon execution of DLAM **114** by processing unit **112**. Referring to FIG. **3**, it should be noted that method **300** largely resembles to method **200** with the exception that method **300** utilizes two separate and simultaneous processes or routines (as opposed to the single process/routine of method **200**). In some aspects, DLAM **114** can utilize an "interrupt routine function" to handle the clock timer. For example, the clock timer can be configured to run on a periodic basis, which occasionally interrupts the main routine. Referring to FIG. **3**, a first process including steps **302**, **304**, and **305** can be configured to execute on a continuous basis. Similarly, a second process including steps **306**-**320** can be configured to execute in parallel with the first process. In one aspect, processing unit **112** can execute both the first process and the second process in an alternating manner such that the two separate processes seem to run simultaneously or contemporaneously.

In one aspect, method **300** comprises a step **302** where a lighting adjustment input is received. In one aspect, a user can adjust a control unit (e.g., control unit **102**), such as a dimmer slider, configured to control the illumination output of an LED light fixture. Upon adjusting the dimmer slider, a transmitter unit (e.g., transmitter unit **106**) associated with the dimmer switch can be configured to transmit a wireless signal that comprises a lighting adjustment input command to the LED light fixture (e.g., LED light fixture **104**). Notably, step **302** is identical to step **202** in method **200** of FIG. **2** as discussed above.

In step **304**, a determination as to whether the received lighting adjustment signal is new can be made. In some aspects, step **304** can be an optional step used in wireless control systems. If the received light adjustment signal is determined not to be a new lighting adjustment input, then method **300** can simply return to step **302** and wait for the receiving of a new lighting adjustment input. If the received lighting adjustment signal is determined to be a new lighting adjustment input in step **304**, then method **300** can then proceed to step **305** where the input command signal is stored as a new target lighting level. In the event a new target lighting level is set, DLAM **114** can be configured to utilize the new target lighting level in the second process. For example, DLAM **114** can utilize the new target lighting level to compare with the current lighting level value in step **308**.

Referring to the second process of FIG. **3**, step **306** comprises a determination of whether the clock timer (e.g., a portion of a processor in the LED light fixture) has expired. In one aspect, step **306** comprises a periodic check to determine if the clock timer has expired. In some aspects, the clock timer mechanism included in the LED light fixture can receive a step time value (explained below) and waits until the step time value expires before proceeding to the steps of method **300**. Specifically, if the step time value has expired, then method **300** can continue to step **308**. Otherwise, method **300** loops back to step **306** until a new target lighting level is received.

Upon determining that the target lighting level is not equal to the current lighting level at step **308**, method **300** continues to step **310**. At this stage, steps **310-320** of method **300** proceed in a manner identical to steps **210-220** (as described above) of method **200** with the exception that step **320** loops back to step **306** (as opposed to step **220** looping back to step **202**).

As mentioned above, FIG. **4** is a graph illustrating an exemplary association between brightness percent and lighting gradation steps corresponding to an LED light fixture according to one aspect of the disclosure herein. As shown in FIG. **4**, a logarithmic curve represents an association between an LED light fixture's 256 gradation steps (e.g., gradation steps 0 to 255) to the percentage of total light brightness produced by the same LED light fixture. Specifically, the logarithmic curve in FIG. **4** illustrates that at lower gradation steps (i.e., gradation steps 0 to 150), less than 10% of the LED light fixture's illumination is emitted. However, as the gradation steps increase linearly, the brightness percent of the LED light fixture increases exponentially. For example, nearly 80 percent of the brightness percent of the LED light fixture is emitted during gradation steps 200 to 255 (i.e., 56 steps). Notably, a logarithmic curve or polynomial can be utilized to effectively determine the rate in which the brightness of the LED light fixture is increased since a human eye typically perceives increases in light brightness at lower illumination levels than at higher illumination levels. Specifically, in order for the human eye to perceive a gradual and steady increase in brightness, the increase of illumination brightness must be conducted at a variable rate (i.e., smaller increases of brightness at lower gradation steps and larger jumps of brightness at higher gradation steps). Although a scale of 0 to 255 gradation level/steps are depicted in FIG. **4**, any number of gradation steps can be utilized without departing from the scope of the present subject matter.

As mentioned above, FIG. **5** depicts portions of an exemplary association between brightness percent and lighting gradation steps corresponding to an LED light fixture according to one aspect of the disclosure herein. Notably, FIG. **5** comprises three separate sections **502-506** of a table that contains the numerical data used to plot the logarithmic curve depicted in FIG. **4**. Section **502** comprises brightness percentage data associated with gradation steps 0-25. Notably, less than a 0.10 percent increase in brightness is associated with the increase from gradation step 0 to gradation step 25. In contrast, section **504** illustrates almost a 6 percent increase in brightness that corresponds to the increase from gradation step 151 to gradation step 176. Moreover, section **506** illustrates a nearly 50 percent increase in brightness that is associated with the increase from gradation step 230 to gradation step 255. Although FIG. **5** depicts data that is used to produce the exemplary logarithmic curve shown in FIG. **4**, other types of exponential, polynomial, and logarithmic equations can be used to generate plot point tables not unlike those provided in FIG. **5**.

FIG. **6** is an exemplary table illustrating the mapping of the gradation step delta and step times according to one aspect of the disclosure herein. Referring to FIG. **6**, table **600** comprises a pulse width modulation (PWM) delta column **602** and a step time column **604**. Notably, PWM delta column **602** lists a plurality of "delta values" that represent the absolute value of the difference between a target lighting gradation step and a current lighting gradation step. For example, suppose a control unit associated with an LED light fixture is initially set to a current lighting gradation step/setting (e.g., an initial lighting gradation step/setting) equal to 155 and a user subsequently adjusts a dimmer switch associated with the control unit to lower the illumination level emitted by the LED light fixture to a target lighting gradation step equal to 140. In this scenario, the delta value would equal to 15. Similarly, if the control unit associated with an LED light fixture is initially set to a current lighting gradation step (or setting) equal to 155 and a user subsequently adjusts a dimmer switch associated with the control unit to increase the illumination level emitted by the LED light fixture to a target lighting gradation step equal to 170, the absolute value of delta value would also equal 15.

Regardless of whether the delta value is negative or positive, it should be noted that only the absolute value or magnitude of the calculated delta value is of importance. Namely, the delta value is used to determine the amount of time (i.e., step time) in which the LED light fixture maintains a particular level of brightness before being incremented (or decremented) to the next gradation step. For example, if the delta value is equal to 15, then the associated step time value is equal to 12.608 milliseconds (ms). More specifically, the LED light fixture displays the current lighting level for 12.608 milliseconds before being incremented (or decremented) to the next gradation step. Notably, the next gradation step will be associated with a delta equal to 14, thus indicating an increased step time value equal to 13.12 milliseconds. Notably, by utilizing a lookup table such as table **600** to recalculate the step time at each gradation step, the present subject matter is able to increase or decrease the brightness level of an LED light fixture at a variable rate (i.e., instead of a constant rate). Although FIG. **6** illustrates an exemplary table **600** that contain 32 predefined data points, it is understood that more or less data points can be utilized without departing from the scope of the present subject matter.

While the subject matter herein has been has been described in reference to specific aspects, features, and/or illustrative embodiments, it will be appreciated that the utility of the described subject matter is not thus limited, but rather extends to and encompasses numerous other variations, modifications and alternative embodiments, as will suggest themselves to those of ordinary skill in the field of the present subject matter, based on the disclosure herein. Various combinations and sub-combinations of the structures and features described herein are contemplated and will be apparent to a skilled person having knowledge of this disclosure. Any of the various features and elements as disclosed herein can be combined with one or more other disclosed features and elements unless indicated to the contrary herein. Correspondingly, the subject matter as hereinafter claimed is intended to be broadly construed and interpreted, as including all such variations, modifications and alternative embodiments, within its scope and including equivalents of the claims.

What is claimed is:

1. A method for dynamically controlling a light emitting device (LED) lighting fixture, comprising:

receiving, at an LED lighting fixture, a lighting adjustment signal corresponding to a target lighting level;

determining a delta value that represents a difference between a current lighting level of the LED lighting fixture and the target lighting level and a step time value associated with the determined delta value, wherein the step time value increases as the delta value reduces in magnitude; and

adjusting the current lighting level of the LED lighting fixture to a new current lighting level for the duration of the step time value.

2. The method of claim **1**, comprising repeating the determining and adjusting steps until the new current lighting level equals the target lighting level.

3. The method of claim **1**, wherein the delta value comprises a difference of gradation steps existing between the current lighting level and the target lighting level.

4. The method of claim **3**, wherein adjusting the current lighting level further comprises increasing the current lighting level to the new current lighting level, wherein the new current lighting level comprises a single gradation step greater than the current lighting level.

5. The method of claim **3**, wherein adjusting the current lighting level further comprises decreasing the current lighting level to the new current lighting level, wherein the new current lighting level comprises a single gradation step less than the current lighting level.

6. The method of claim **1**, wherein determining the delta value comprises subtracting the current lighting level from the target lighting level.

7. The method of claim **1**, wherein the step time value is determined by using the delta value to query a lookup table.

8. The method of claim **1**, wherein the step time value is determined by using a mathematical formula that receives the delta value as an input.

9. The method of claim **1**, wherein adjusting the current lighting level comprises emitting light from the LED light fixture at a brightness percentage value determined by using the new current lighting level to either utilize a lookup table or a mathematical formula.

10. The method of claim **9**, wherein the lookup table is configured to be missing entries such that one or more gradation steps are skipped.

11. The method of claim **1**, wherein adjusting the current lighting level comprises emitting light from the LED light fixture at a brightness percentage value determined by using the new current lighting level to reference either a logarithmic curve or a polynomial.

12. The method of claim **1**, wherein the lighting adjustment signal is received from a control unit via either a wireless connection or a wired connection.

13. A dynamic light emitting device (LED) lighting adjustment system comprising:

an LED light fixture comprising:

a receiver unit configured to receive a lighting adjustment signal corresponding to a target lighting level; and

a dynamic lighting adjustment module configured to:

determine a delta value that represents a difference between a current lighting level of the LED lighting fixture and the target lighting level and a step time value associated with the determined delta value, wherein the step time value increases as the delta value reduces in magnitude; and

adjust the current lighting level of the LED lighting fixture to a new current lighting level for the duration of the step time value.

14. The system of claim **13**, wherein the dynamic lighting adjustment module is further configured to repeatedly determine the delta value and step time value and adjust the current lighting level of the LED lighting fixture until the new current lighting level equals the target lighting level.

15. The system of claim **13**, wherein the delta value comprises a difference of gradation steps existing between the current lighting level and the target lighting level.

16. The system of claim **15**, wherein the dynamic lighting adjustment module is further configured to increase the current lighting level to the new current lighting level, wherein the new current lighting level comprises a single gradation step greater than the current lighting level.

17. The system of claim **15**, wherein the dynamic lighting adjustment module is further configured to decrease the current lighting level to the new current lighting level, wherein the new current lighting level comprises a single gradation step less than the current lighting level.

18. The system of claim **13**, wherein the dynamic lighting adjustment module is further configured to calculate the delta value by subtracting the current lighting level from the target lighting level.

19. The system of claim **13**, wherein the step time value is determined by using the delta value to query a lookup table.

20. The system of claim **13**, wherein the step time value is determined by using a mathematical formula that receives the delta value as an input.

21. The system of claim **13**, wherein the dynamic lighting adjustment module is further configured to instruct the LED light fixture to emit light at a brightness percentage value determined by using the new current lighting level to either utilize a lookup table or a mathematical formula.

22. The system of claim **21**, wherein the lookup table is configured to be missing entries such that one or more gradation steps are skipped.

23. The system of claim **13**, wherein the dynamic lighting adjustment module is further configured to instruct the LED light fixture to emit light at a brightness percentage value determined by using the new current lighting level to reference either a logarithmic curve or a polynomial curve.

24. The system of claim **13**, wherein a control unit is configured to send the lighting adjustment signal via either a wireless connection or a wired connection.

25. A non-transitory computer readable medium having stored thereon comprising computer executable instructions that, when executed by a processor of a computer, performs steps comprising:

receiving, at a light emitting device (LED) lighting fixture, a lighting adjustment signal corresponding to a target lighting level;

determining a delta value that represents a difference between a current lighting level of the LED lighting fixture and the target lighting level and a step time value associated with the determined delta value, wherein the step time value increases as the delta value reduces in magnitude; and

adjusting the current lighting level of the LED lighting fixture to a new current lighting level for the duration of the step time value.

26. The computer readable medium of claim 25, comprising repeating the determining and adjusting steps until the new current lighting level equals the target lighting level.

27. A method for dynamically controlling a light emitting device (LED) lighting fixture, comprising:

receiving, at an LED lighting fixture, a lighting adjustment signal corresponding to a target lighting level;

determining a delta value that represents a difference between an initial lighting level of the LED lighting fixture and the target lighting level; and

adjusting a lighting level of the LED lighting fixture from the initial lighting level to the target lighting level at a rate that decreases as the lighting level approaches the target lighting level,

wherein the rate is determined using a mathematical formula that receives the delta value as an input.

28. The method of claim 27, wherein the delta value comprises a difference of gradation steps existing between the initial lighting level and the target lighting level.

29. The method of claim 28, wherein adjusting the lighting level includes decreasing the rate at which the lighting level is adjusted as a difference between the gradation steps decreases.

30. The method of claim 27, wherein the rate is determined using the delta value to query a lookup table.

31. A dynamic light emitting device (LED) lighting adjustment system comprising:

an LED light fixture comprising:

a receiver unit configured to receive a lighting adjustment signal corresponding to a target lighting level; and

a dynamic lighting adjustment module configured to:

determine a delta value that represents a difference between an initial lighting level of the LED lighting fixture and the target lighting level using a mathematical formula that receives the delta value as an input; and

adjust a lighting level of the LED lighting fixture from the initial lighting level to the target lighting level at a rate that decreases as the lighting level approaches the target lighting level.

32. The system of claim 31, wherein the delta value comprises a difference of gradation steps existing between the initial lighting level and the target lighting level.

33. The system of claim 32, wherein the dynamic lighting adjustment module is further configured to decrease the rate at which the lighting level is adjusted as a difference between the gradation steps decrease.

34. The system of claim 31, wherein the dynamic lighting adjustment module is further configured to determine the rate using the delta value to query a lookup table.

* * * * *